

<p align="center">LLNL Environmental Restoration Division Standard Operating Procedure</p>	<p align="center">TITLE: Hydraulic Testing (Slug/Bail)</p>
<p>APPROVAL _____ Date _____</p> <p>Environmental Chemistry and Biology Group Leader</p>	<p align="center">PREPARERS: T. Berry*, J. Chiu*, R. Ferry*, S. Nelson*, and E. Nichols*</p> <p align="center">REVIEWERS: T. Carlsen and V. Dibley</p>
<p>APPROVAL _____ Date _____</p> <p>Division Leader</p> <p>CONCURRENCE _____ Date _____</p> <p>QA Implementation Coordinator</p>	<p align="center">PROCEDURE NUMBER: ERD SOP-3.3</p> <p align="center">REVISION: 2</p> <p align="center">EFFECTIVE DATE: December 1, 1995</p> <p align="center">Page 1 of 14</p>

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1.0 PURPOSE

To determine saturated hydraulic conductivity of the sediments near the well screen under *in situ* conditions without pumping the well.

2.0 APPLICABILITY

This procedure is applicable for slug/bail hydraulic testing. Slug/bail tests are only recommended for wells that produce less than 1 gallon per minute.

3.0 REFERENCES

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4.0 DEFINITIONS

4.1 Slug/Bail Test

A slug/bail test measures the recovery of the ground water level in a well due to an instantaneous change in pressure.

5.0 RESPONSIBILITIES

5.1 Division Leader

The Division Leader's responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

5.2 Field Personnel

Field personnel are responsible for conducting and documenting hydraulic testing according to this procedure.

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6.0 PROCEDURES

6.2 Discussion

- 6.1.1 During the slug test, a slug of known volume is lowered into the well displacing that same volume of water. Over time, typically a few hours, the water level returns to static. During the test, water-level measurements are recorded using a pressure transducer and a data logger. These measurements, plotted against time, produce a curve which is then compared to type-curves to determine values of T and K. For a bail test, the slug is removed from the well, and water-level measurements are collected similar to the slug test.
- 6.1.2 The advantages and limitations of using slug/bail tests to estimate hydraulic properties include: 1) estimates can be made *in situ*, and errors incurred in laboratory testing of disturbed samples are avoided; 2) tests can be quickly performed at a relatively low cost, because a pumping well and observation wells are not required; 3) the hydraulic conductivity of small volumes within an aquifer can be estimated; 4) no treatment, collection, or disposal of pumped water is necessary; 5) only the hydraulic properties of the material very near the well are estimated, and they may not be representative of the average hydraulic properties of the area; 6) certain assumptions are made in the analysis, and if they are inconsistent with the geologic conditions at the site, the slug/bail test results may be invalid; 7) the storage coefficient (*S*) usually cannot be determined; and 8) sufficient data for analysis may not be collected if the hydraulic conductivity of the screened material is relatively high.

6.2 Office Preparation

- 6.2.1 Review the Daily Operations Guide and associated SOPs. Information on depth to water, depth of well, screened interval, and casing size is obtained from the Data Management Group (DMG) for established wells, or from the drilling coordinator for new wells.
- 6.2.2 Coordinate schedules/actions with task leader/study area leader, or sampling coordinators, as appropriate.
- 6.2.3 Review the operator's manual provided with the electronic data logger, if appropriate.
- 6.2.4 Check out and ensure the proper operation of all field equipment. Ensure that the electronic data logger is fully charged, if appropriate. Test the electronic data logger and pressure transducers using a container of water (e.g., sink or bucket of water). Always bring additional transducers in case of malfunctions.
- 6.2.5 Obtain the Hydraulic Test Logbook and a sufficient number of field forms to complete the field assignment.
- 6.2.6 Review appropriate sections of the Site Safety Plan.

6.3 Field Preparation

- 6.3.1 If the well has a Well Wizard bladder pump installed, it must be removed at least one day before the test is conducted to allow the water level to return to static.
- 6.3.2 Locate monitor wells to be tested and appropriate decontamination areas.

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- 6.3.3 Assemble appropriate testing equipment listed in the Equipment Checklist (Attachment A).
- 6.3.4 To avoid cross-contamination, bailers or measuring devices should be cleaned before and after each test. If water is added to the monitoring well, it should be from an uncontaminated source and be transported in a clean container. Decontaminate the transducer and cable as specified in SOP 4.5, "General Equipment Decontamination."
- 6.3.5 Calibrate all gauges and transducers before conducting slug test according to SOP 3.2, "Pressure Transducer Calibration." Document instrument calibration in the Hydraulic Test Logbook.
- 6.3.6 Measure initial water level in monitor well or piezometer according to SOP 3.1, "Water Level Measurement," and record on Aquifer Test Data Sheet (Attachment B).
- 6.3.7 Before beginning the slug test, enter and record information in the electronic data logger. The type of information will vary depending on the model used. When using different models, consult the operator's manual for the proper data entry sequence to be used. For example, the following data is entered into the Enviro-Labs Model DL-120-MCP Data Logger:
 1. Baud rate.
 2. Station ID.
 3. Date (YY/MM/DD).
 4. Time (HH:MM:SS).
 5. Scale factors for each channel.
 6. Logging sequence.
- 6.3.8 Test wells from least contaminated to most contaminated, if possible.

6.4 Operation

The following general procedures will be used to collect and report slug/bail test data. The procedures required for a particular slug/bail test may vary slightly from those described, depending on site conditions. Modifications to the test procedures should be documented on the Aquifer Test Data Sheet (Attachment C, Slug Test Schematic).

- 6.4.1 When the slug/bail test is performed using an electronic data logger and pressure transducer, most of the data will be electronically stored internally or on computer diskettes or tape. The information will be transferred directly to the main computer and analyzed. A Aquifer Test Data Sheet with supplemental information and a computer printout of the data should be maintained with the Data Management Group (DMG) as documentation.
- 6.4.2 The time required to complete a slug test is a function of the volume of the slug, the transmissivity of the formation, and the well casing size. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. Test length may range from less than a minute to several hours.
- 6.4.3 Slug tests must be conducted on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped, measure the water level

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within 0.1 ft of the static water level before sampling. At least one week should elapse between well development and the slug test.

- 6.4.4 The slug will have to remain completely submerged throughout the test, so the height of the static water column must be greater than the length of the slug.
- 6.4.5 A pressure transducer must hang below the bottom of the submerged slug so a portion of the water column must be available for the transducer.
- 6.4.6 The slug diameter must be small enough so that it will not disturb the transducer cable when the slug is lowered.
- 6.4.7 Although a larger slug is desired when possible, using a large slug that is unwieldy can result in unnecessary difficulties and/or damage to the pressure transducer.
- 6.4.8 Well diameter, screened interval, total depth, and most recent, depth-to-water information should be used to determine the appropriate slug size. A slug of appropriate size may need to be constructed.

Note: In general, slug size will not be restricted by the height of the water column, but double check to prevent having to redo a test.

- 6.4.9 The Aquifer Test Data Sheet is used to record observations and supplemental information. Complete the form as follows:
 - 1. Site Location. Brief description of the general location of the well.
 - 2. Well ID. Unique number assigned to each well where measurements are taken.
 - 3. Date. The date of the test.
 - 4. Make of logger used (Campbell or Hermit) and the make and serial number of the transducer used.
 - 5. Slug Dimensions or Volume of Water. Dimensions of the slug or displacement object in tenths of feet.
 - 6. Personnel. Initials of personnel performing field measurements or collecting samples.
 - 7. Test Type. The slug device is either injected (slug) or withdrawn (bail) from the monitor well. Note the appropriate test type.
 - 8. Comments. Appropriate observations or information for which no other blanks are provided.
 - 9. Elapsed Time (min:sec). Cumulative time readings from beginning of test to end of test in minutes and seconds.
 - 10. Depth to Water (ft). Depth of water recorded in tenths and hundredths of feet.

6.5 Procedure for Conducting a Slug/Bail Test.

- 6.5.1 Measure the static water level in the well, and record in Hydraulic Test Logbook and on the Aquifer Test Data Sheet. The point and time of measurement should be noted on the Aquifer Test Data Sheet and in the wellhead logbook.
- 6.5.2 Cover sharp edges of the well casing with duct tape to protect the transducer cables.

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- 6.5.3 Connect the transducer cable to the electronic data logger.
- 6.5.4 Slowly lower the transducer and cable down the well to a depth below the slug submergence for the test, but at least 1 ft from the bottom of the well. Be sure this depth is within the design range stamped on the transducer. To keep the transducer at a constant depth, securely tape the transducer cable to a stationary object.
- 6.5.5 Firmly tie one end of the rope to the slug. From the top of the slug, measure a length slightly greater than the depth-to-water, and mark the rope with a duct tape tag. Then, measure the length needed at the duct tape tag to hang the slug a few inches above the static water level, and mark this with a second duct tape tag. Account for any possible stretching of the rope.
- 6.5.6 Tie the other end of the rope to an anchor so that the slug can be lowered within a few inches of the water level.

Note: Account for “stretch” of the rope by being a little conservative in estimating where the slug will hang.

- 6.5.7 Slowly lower the slug into the well and let it hang a few inches above the water as mentioned in Step 6. Have the data logger display the transducer readout while lowering the transducer. If the slug does contact the water, an immediate change will be seen. On the logger readout, use the lower duct tape tag as a reference point.

Note: Touching the water with the slug is not always disastrous. If the slug does touch the water, pull it back up a few inches and see if the water level returns to static in the next few minutes or so.

- 6.5.8 Once the slug is hung, set the data logger to a logging schedule of:

- 1-second intervals for 20 seconds
- 1-second intervals for 40 seconds (20 intervals)
- 5-second intervals for 1 minute (12 intervals)
- 10-second intervals for 1 minute (6 intervals)
- 30-second intervals for 7 minutes (14 intervals)
- 1-minute intervals (on the minute) thereafter

These intervals are already set on the Campbell logger, and logging will commence the moment it is turned on.

- 6.5.9 To begin the test, turn the logger on 5 seconds prior to lowering the slug. It is preferable to begin logging on an even minute and to lower the slug 5 seconds after (e.g., 10:00:00 “logging on,” 10:00:05 “slug lowered”). Quickly lower the slug to the second duct tape mark (see Step 5) and tie off the rope. Do not splash the water.

Note: Sometimes, it is possible to tie the rope to two different anchors so that when the rope is untied from the first position (slug just above the water), it can be dropped and the second anchor will hold it at the desired depth (see Figure 5-1 “Before Start of Slug Test” and “After Start of Slug Test”).

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- 6.5.10 Another method is to introduce a solid cylinder of known volume to displace and raise the water level, allow the water level to restabilize, and remove the cylinder. It is important to remove or add the volumes as quickly as possible because the analysis assumes that an instantaneous change in pressure is created in the well. It is important to ensure that the slug is completely submerged if introduced.
- 6.5.11 Note on the logger readout the initial rise in the water level and see if it corresponds with the calculated rise. Since the water level changes fairly rapidly at first, it may be necessary to scroll back through the logged data to determine the first (highest) point. (See sections on data loggers).
- Note: This initial rise calculation often does not exactly correspond with the logged initial rise, but it should be relatively close.
- 6.5.12 At some point during the test, take at least one depth-to-water measurement with the water level probe to ensure the transducer is reading correctly.
- 6.5.13 When the water level has returned to static level, the bail test is then performed.
- 6.5.14 Reset logging mode on an even minute, then pull out the slug as quickly as possible. Note the decrease in water level.
- 6.5.15 At each reading, measure depth to water (to the nearest 0.01 ft) and record time when pressure change is at time zero. The number of depth-time measurements necessary to complete the test are variable. Frequent measurements should be made so that the change in water level between two consecutive measurements is <5% of the initial change. It is critical to make as many measurements as possible in the early part of the test.
- 6.5.16 Continue measuring and recording depth-time measurements until the water level returns to within 10% of equilibrium conditions.
- 6.5.17 The test is complete when the water level has returned to static level, and the log equipment can be broken down.

6.6 Post Field Operation

- 6.6.1 Decontaminate or dispose of equipment and rope according to SOP 4.5.
- 6.6.2 If using an electronic data logger:
1. Stop logging sequence.
 2. Save memory.
 3. Disconnect battery at the end of the testing activities.
- 6.6.3 Replace testing equipment in storage containers.

6.7 Office Post Operation

- 6.7.1 Inventory sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- 6.7.2. Replace expendable items.
- 6.7.3 Return equipment to storage area, and report incidents of malfunctions or damage.

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- 6.7.4 Review Hydraulic Test Logbook, and field forms for completeness.
- 6.7.5 Deliver original forms, logger data, and logbooks to DMG with copies to the Project Hydrogeologic Group Leader.
- 6.7.6 Interpret slug/bail test field results with Project Hydrogeologist or Site Manager. Analyze slug/bail test using appropriate software packages or graphical solutions.
- 6.7.7 Send data logger or pressure transducers to factory for recalibration, if needed.

7.0 QA RECORDS

- 7.1 Logbooks
- 7.2 Hydraulic Test Data Sheet

8.0 ATTACHMENTS

- Attachment A—Equipment Checklist
- Attachment B—Aquifer Test Data Sheet
- Attachment C—Slug Test Schematic

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Attachment A

Equipment Checklist

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Equipment Checklist

- _____ 12-volt battery
- _____ Appropriate references and calculator
- _____ Aquifer test sheets
- _____ Calculator, clip board
- _____ Duct tape
- _____ Electric water-level indicator
- _____ Electronic data logger (if transducer method is used)
- _____ Interface probe
- _____ Rope (should very little “stretch”)
- _____ Semilog graph paper (if required)
- _____ Slug (steam cleaned prior to use)
- _____ Steel tape (subdivided into tenths of feet)
- _____ Stopwatch or watch with second hand
- _____ Tape measure (subdivided into tenths and hundredths of feet) or other water-level measuring device
- _____ Watch with a second hand
- _____ Water-pressure transducer (if test is anticipated to last overnight, a barometric pressure transducer should also be used)
- _____ Waterproof ink pen and logbook

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Attachment B

Aquifer Test Data Sheet

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Date _____

AQUIFER TEST DATA SHEET

Well ID: _____ Screen Interval: _____
Project: _____ Pump Intake: _____
Type of Test: _____ Logger: _____

[illegible]

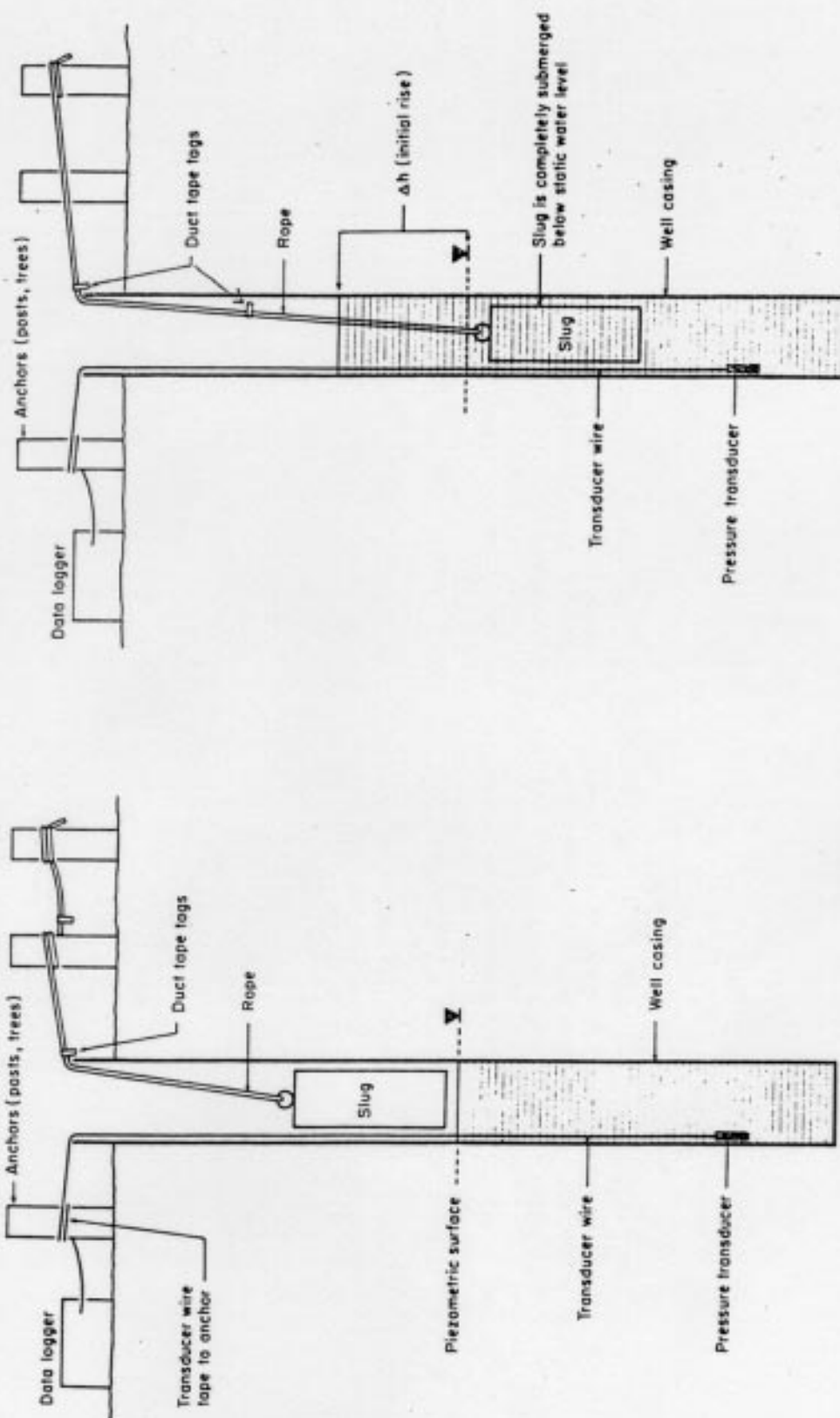
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Attachment C

Slug Test Schematic



WEISS ASSOCIATES



A' Before Start of Slug Test

B: After Start of Slug Test

Figure 5-1 Slug Test